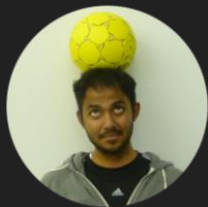


Orko: Facilitating Multimodal Interaction for Visual Exploration and Analysis of Networks

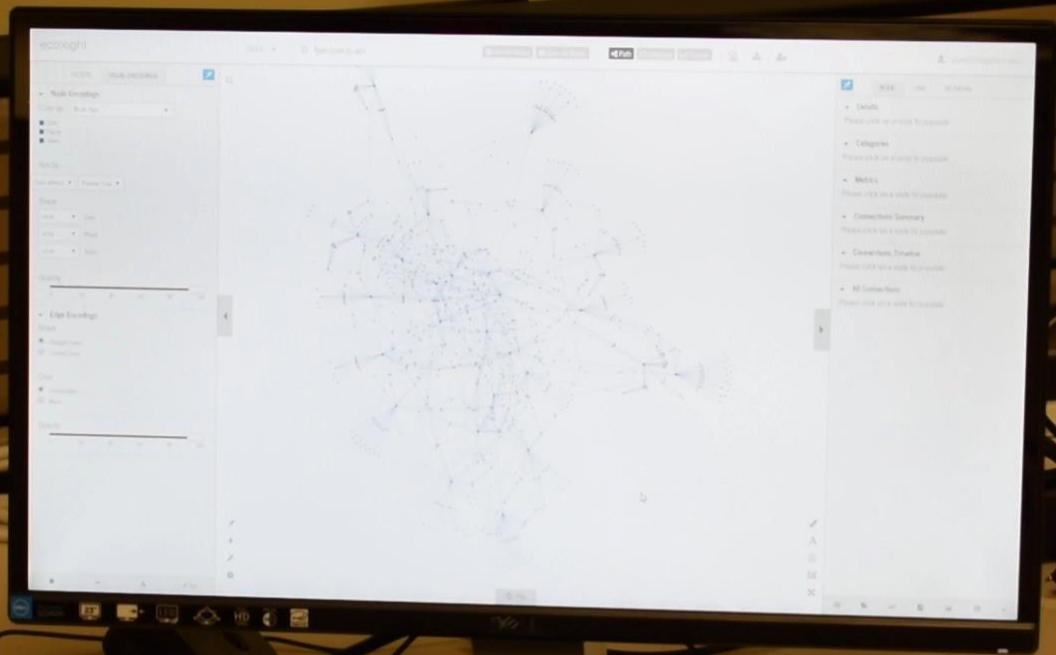


Arjun Srinivasan



John Stasko





EXIT

Microsoft



Process

John Connolly

Mapping connections between people. Design feedback is shown only for connections with up to 3 nodes.



goals

- Roddie Pearce
- Dylan Armstrong
- Christiano Ronaldo
- Wayne Rooney
- Luke Modest
- Thomas Müller
- Wendie Renard
- Basel Dore
- Basel Dore



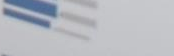
marketValue

- Christiano Ronaldo
- Gerard Pique
- Thomas Müller
- Luke Modest
- Wendie Renard
- Tom Hines
- Samuel Heuser
- Samuel Heuser



club

- Manchester United
- Real Madrid



What is multimodal interaction?

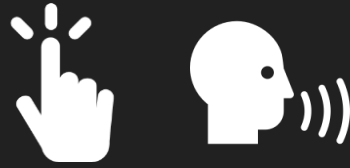
How can we support multimodal interaction for visual data exploration and analysis?

Why support multimodal interaction?

What is multimodal interaction?

Two or more modes of input/output

Two or more modes of input/output



Two or more modes of input/output



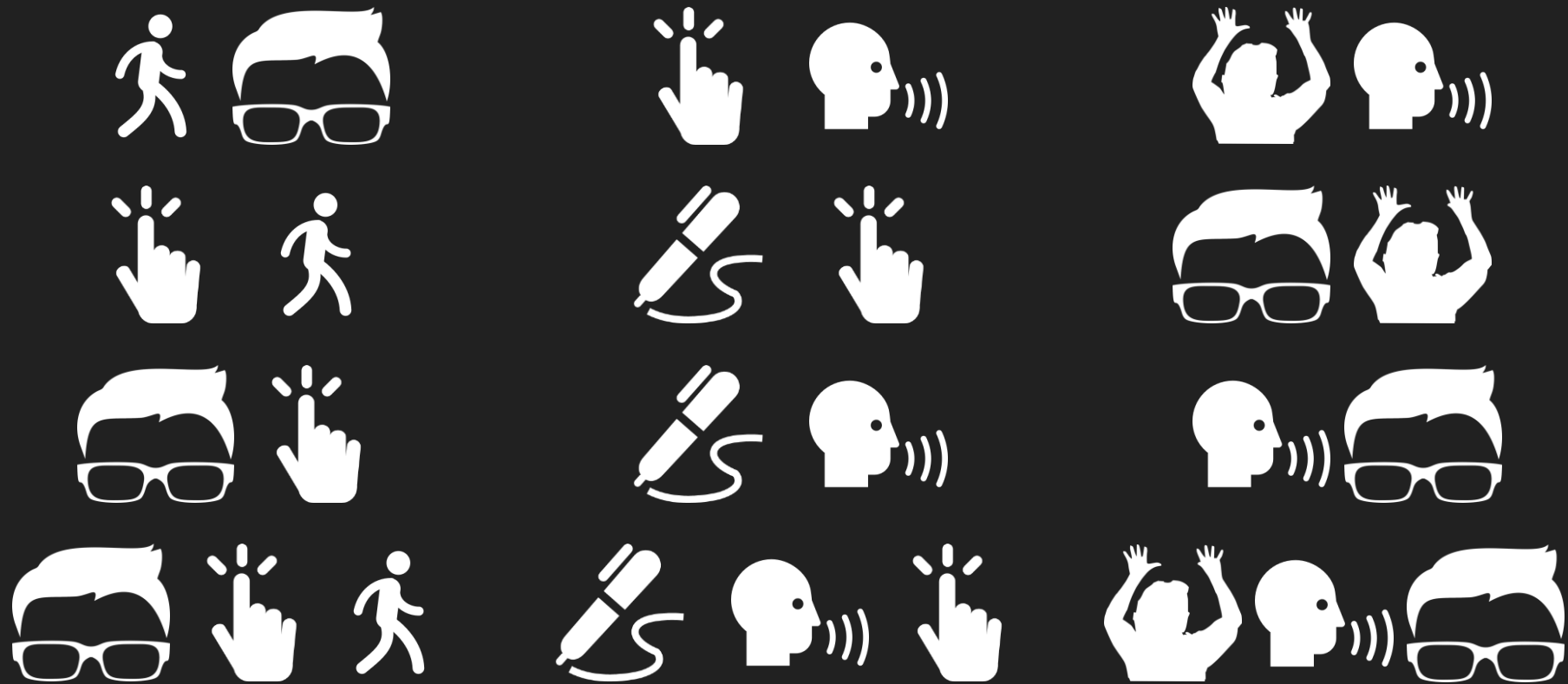
Two or more modes of input/output



Two or more modes of input/output

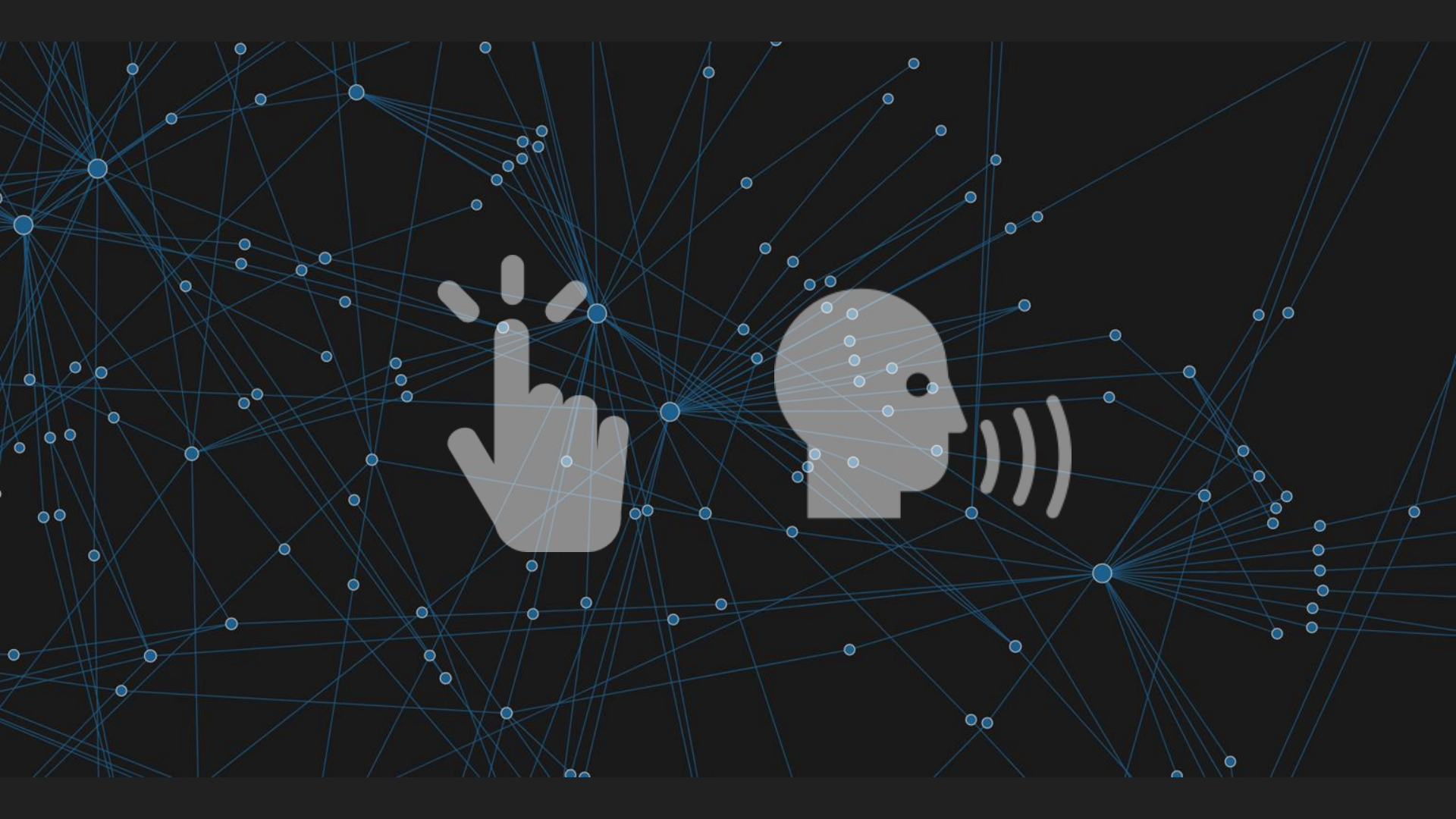


Two or more modes of input/output





Touch & Speech

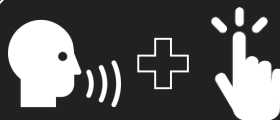




Individual

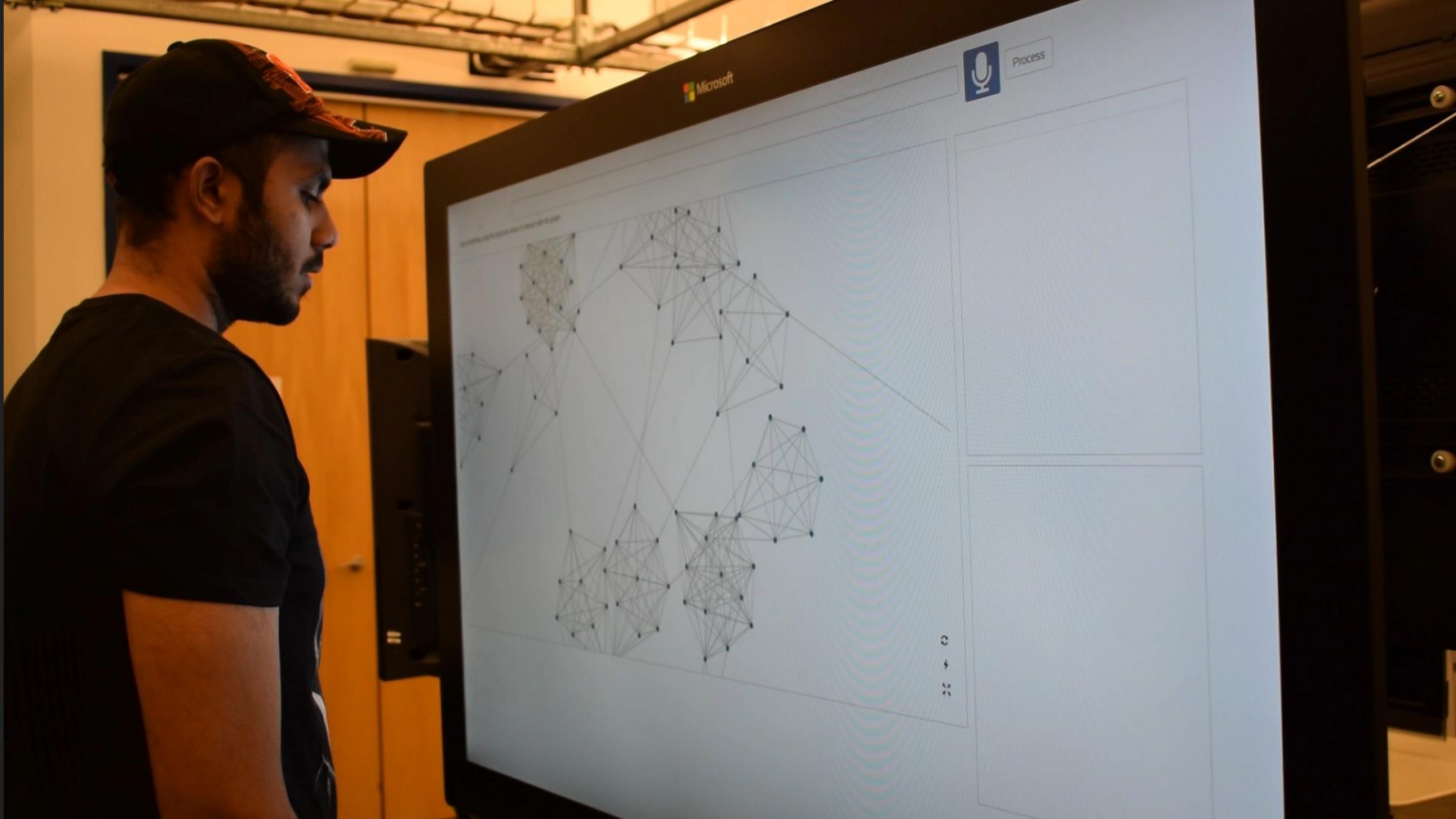
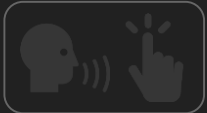


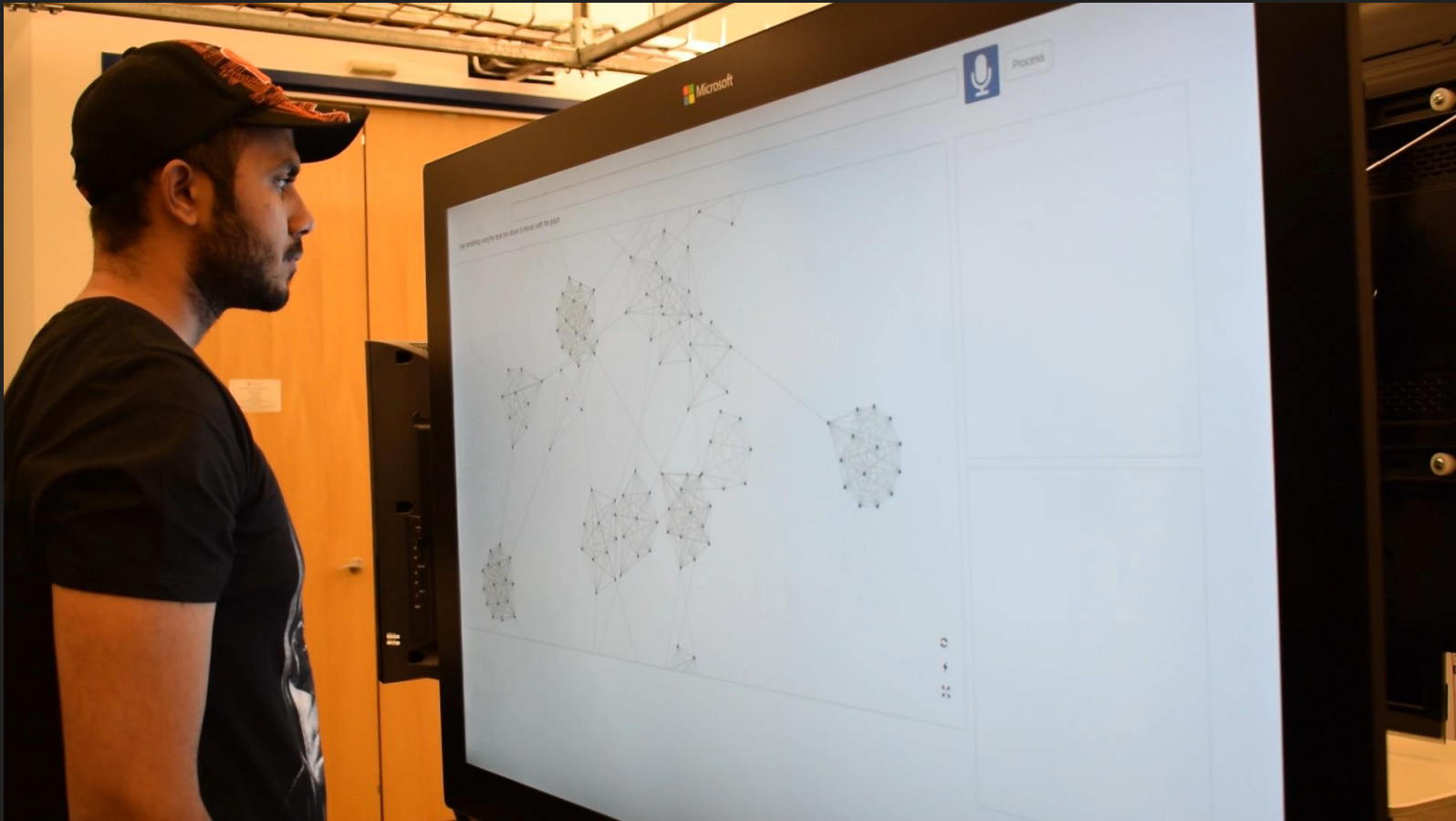
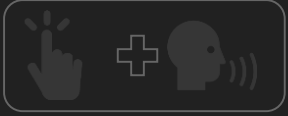
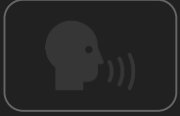
Sequential

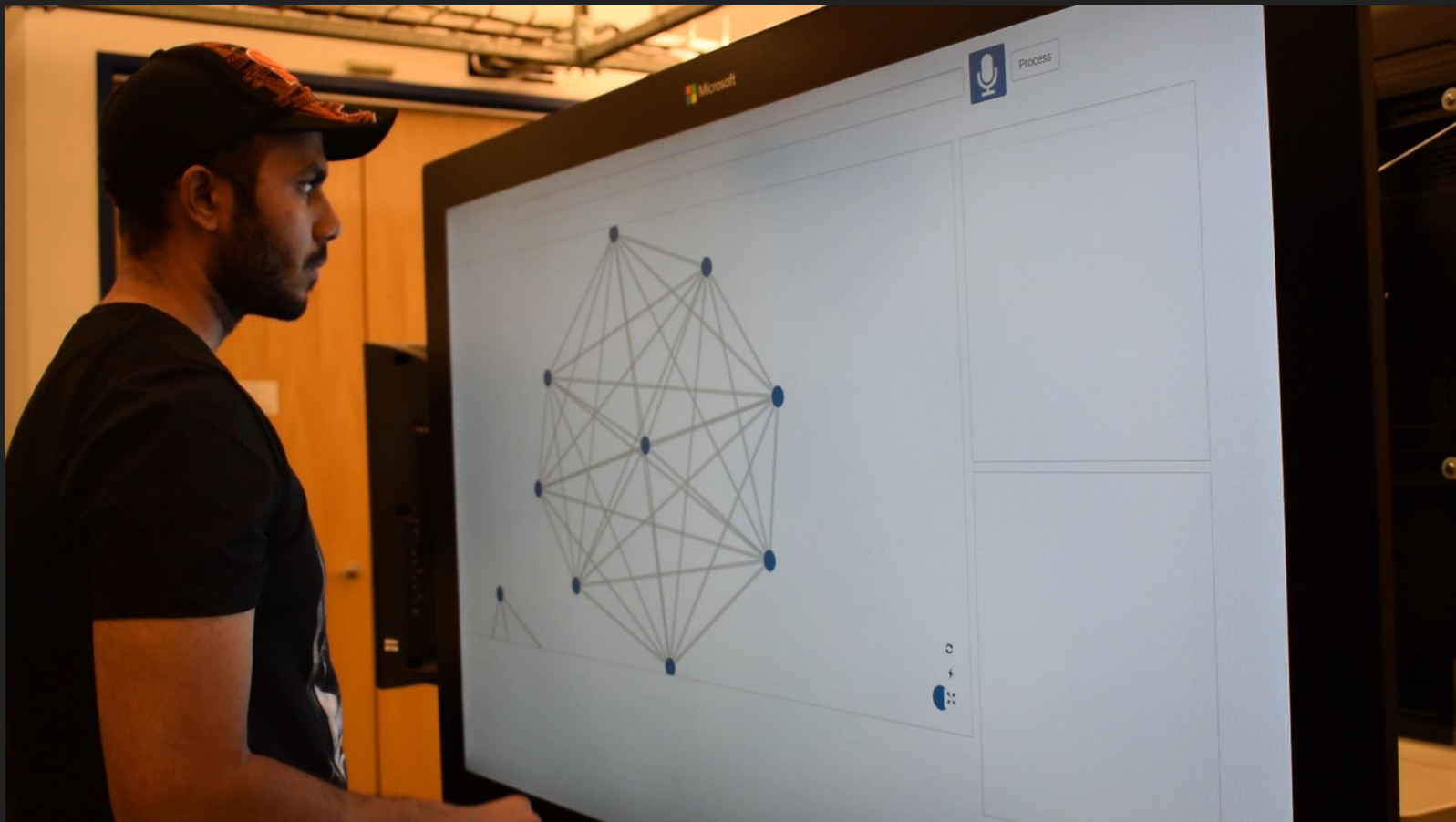
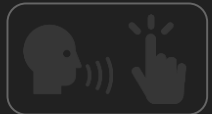
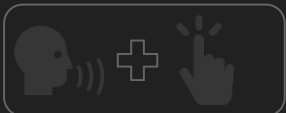
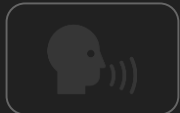
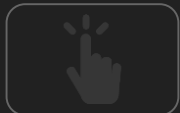


Simultaneous







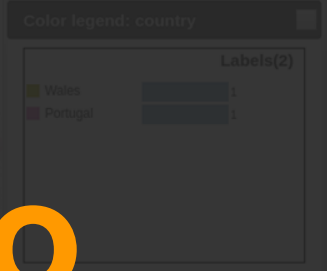


How can we support multimodal interaction for visual data exploration and analysis?

Show their connections

Process

Highlighting nodes directly connected to Gareth Bale and Cristiano Ronaldo



Cristiano Ronaldo

Country: Portugal
 Club: Real Madrid
 Goals scored: 56
 Position: Forward
 Foot: Both
 Market Value: 110000000 USD
 Connections (degree): 29

Gareth Bale and Cristiano Ronaldo play for the same club(Real Madrid).

goals

Cristiano Ronaldo 56
 Gareth Bale 15

country

Wales 1
 Portugal 1

club

Orko

adesso madrid
real madrid

Club: Real Madrid | Color by: Country | Size by: Goals

Goals: 15 - 67



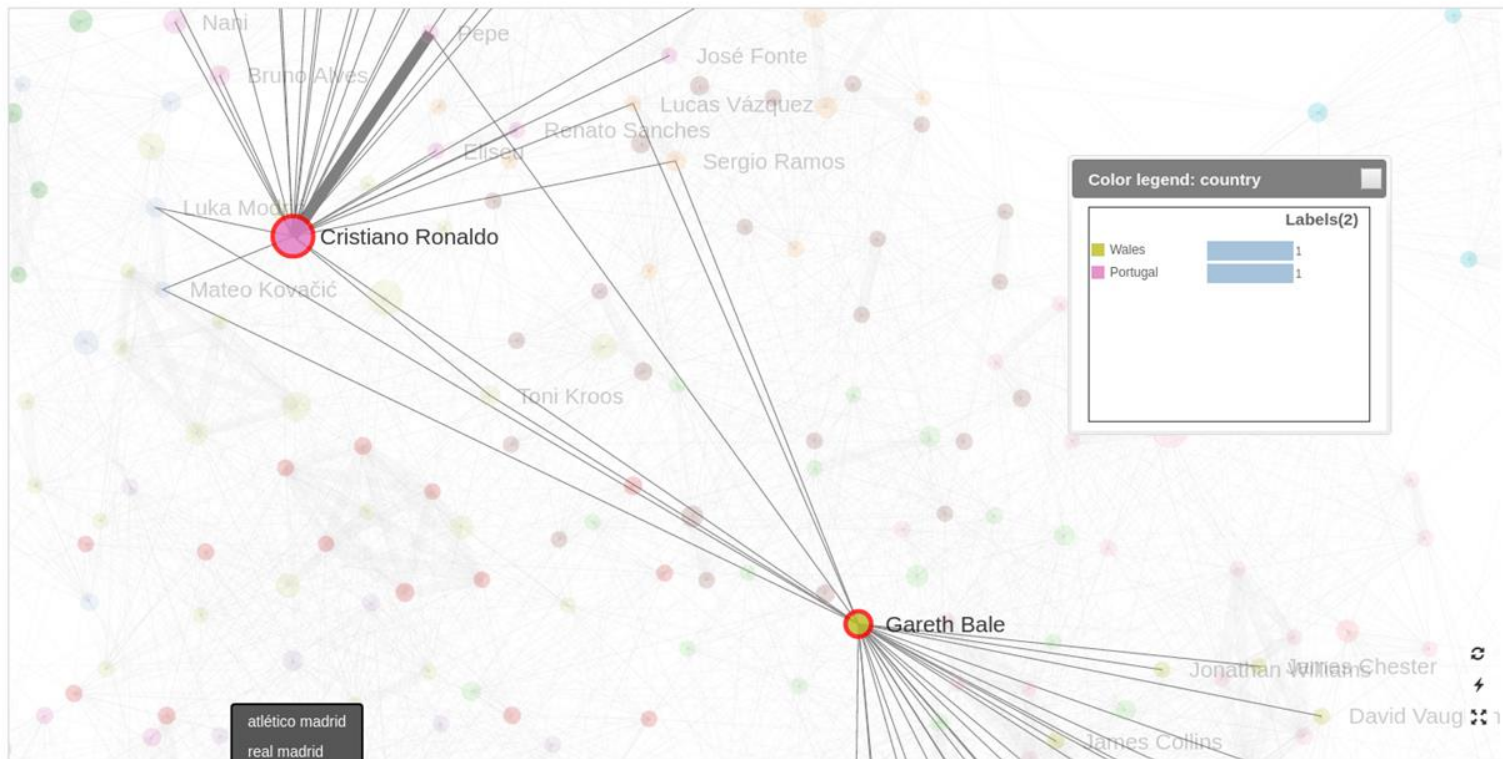
An accomplished Trollan wizard from "He-Man and the Masters of the Universe"

Show their connections



Process

Highlighting nodes directly connected to **Gareth Bale** and **Cristiano Ronaldo**



Cristiano Ronaldo
 Country: Portugal
 Club: Real Madrid
 Goals scored: 56
 Position: Forward
 Foot: Both
 Market Value: 110000000 USD
 Connections (degree): 29

Gareth Bale and Cristiano Ronaldo play for the same club(Real Madrid).



Club: Real Madrid | Color by: Country | Size by: Goals

Goals: 15 - 67

Operations

Find Nodes

Find Connections

Find Path

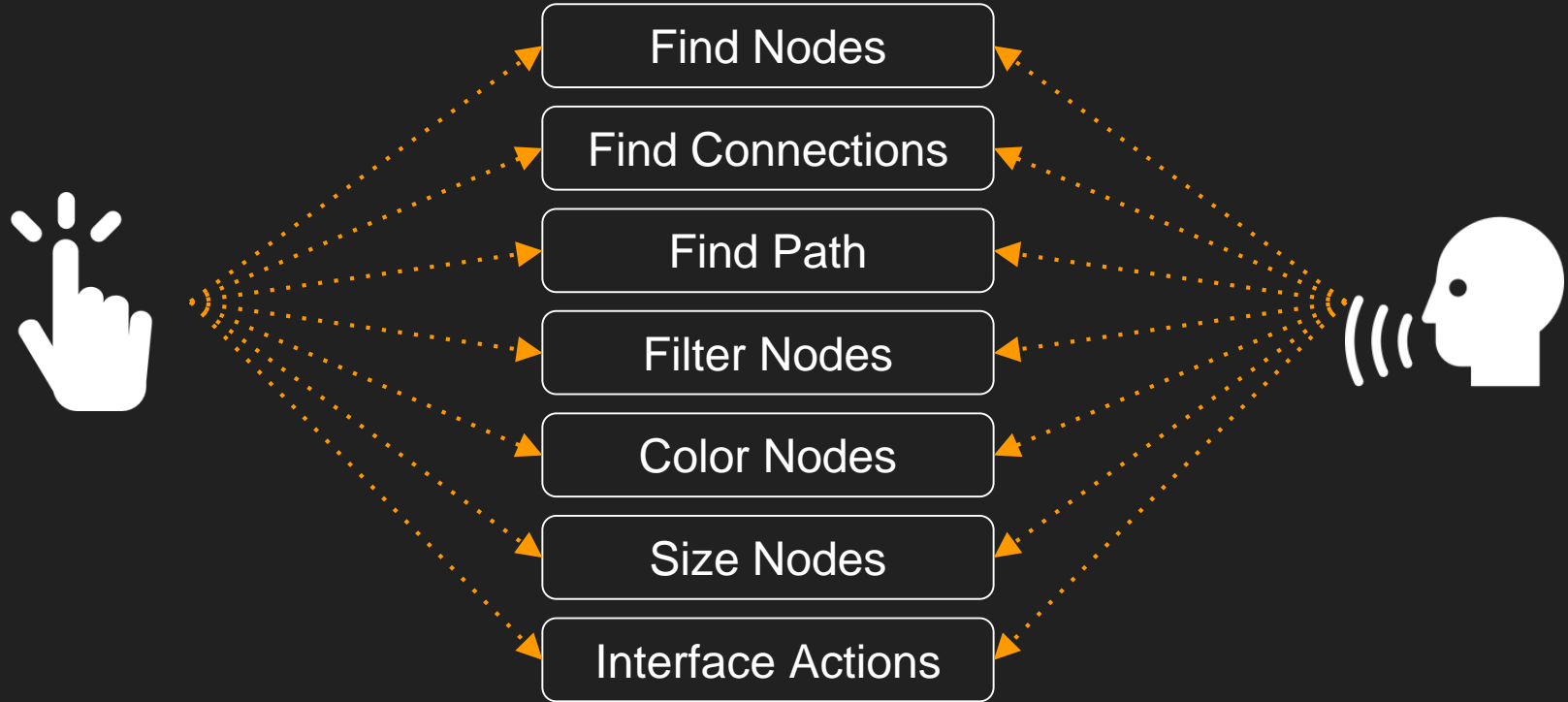
Filter Nodes

Color Nodes

Size Nodes

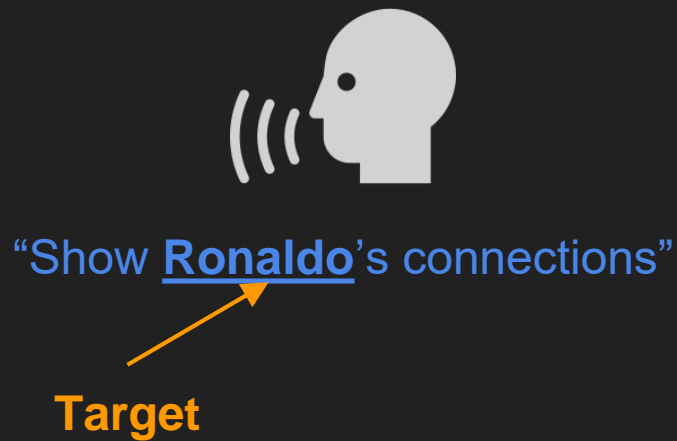
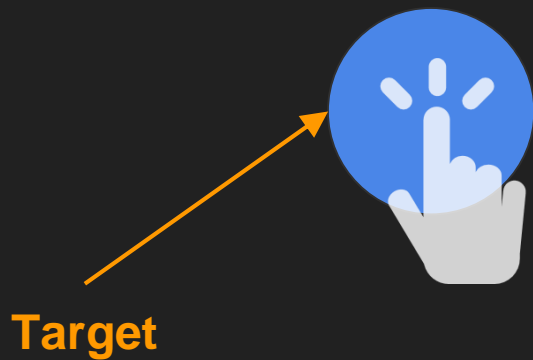
Interface Actions

Operations



Operation:

Find Connections



Explicit

Find Ronaldo's connections.
Show connections between Pogba and Bale.
Highlight the shortest path from Evra to Kroos.
Color by position.
Size nodes by betweenness centrality.
Only show German forwards.

...

Contextual & Follow-up

Are any of these players right footed?
Filter by this player's club.
Show connections of these players.
Color nodes by country > Now club > How about position?
Show German strikers with more than 30 goals > How about French strikers?

...

High-level

How are France and Italy connected?
Players from which countries tend to play more with clubs in the same country?
Find interesting clusters of players.
Modify the network to focus on English players.

...

Explicit

Find Ronaldo's connections.
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High-level

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Modify the network to focus on English players.

...

Show nodes connected to Ronaldo.

Show Ronaldo's connections.

Find players linked to Ronaldo.

Highlight players who play with Ronaldo.

Which players play in the same team as Ronaldo?

Show nodes directly connected to Ronaldo.

Find nodes adjacent to Ronaldo.

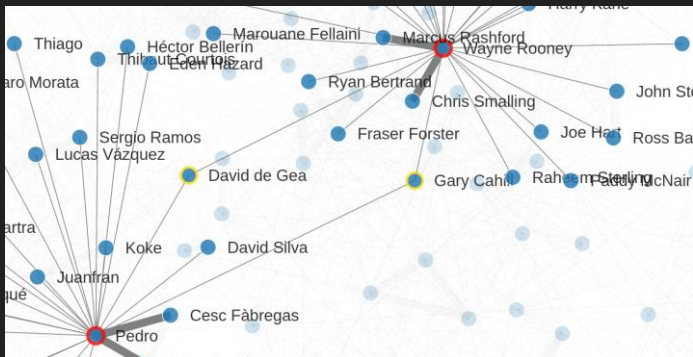
Show Ronaldo's teammates.

Who all is Ronaldo directly connected to?

Find players with a direct link to Ronaldo.

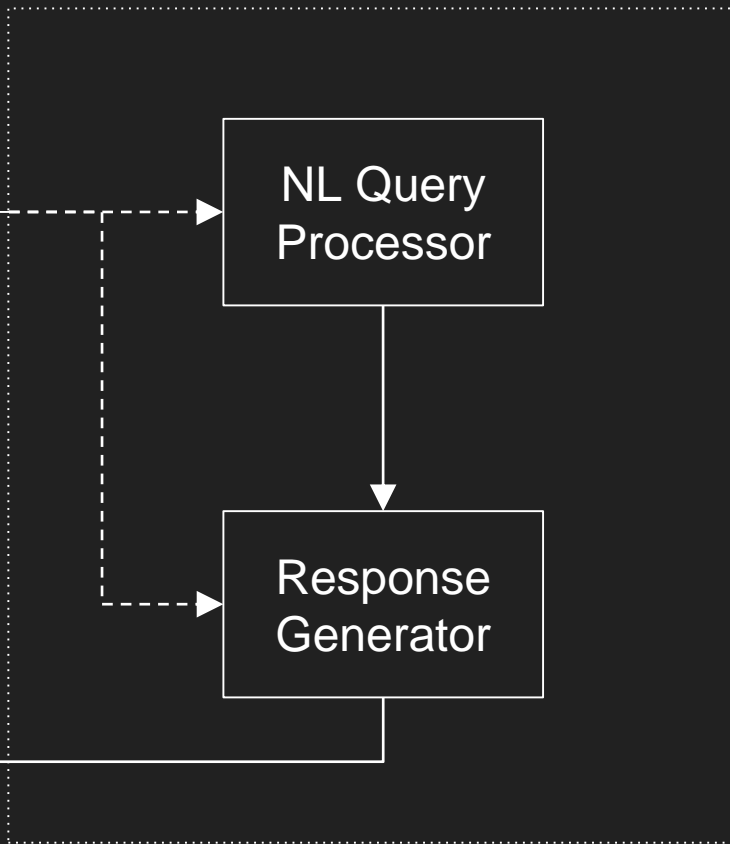
Find direct connections of Ronaldo.

...

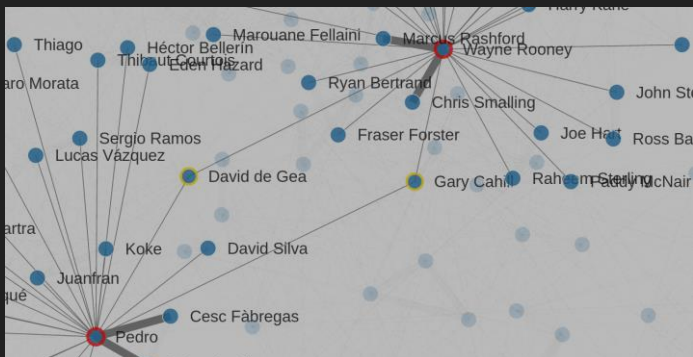


Interface Manager

Response Processor

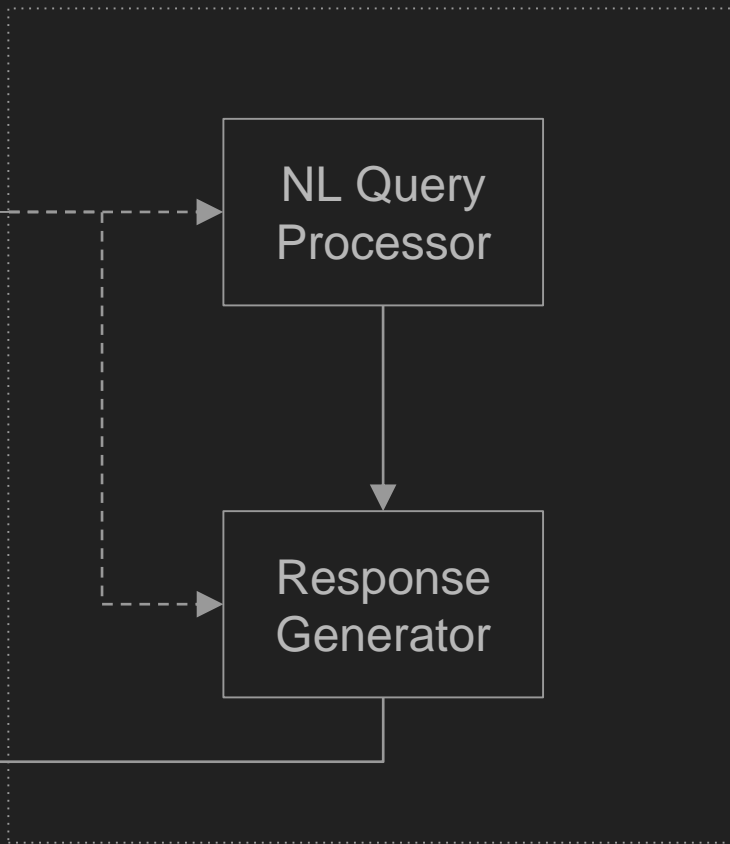


Client Server

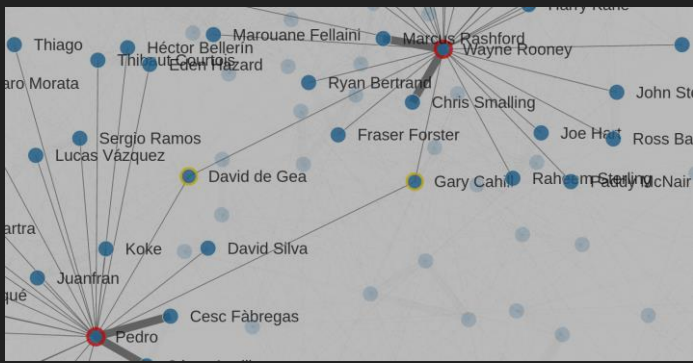


Interface Manager

Response Processor

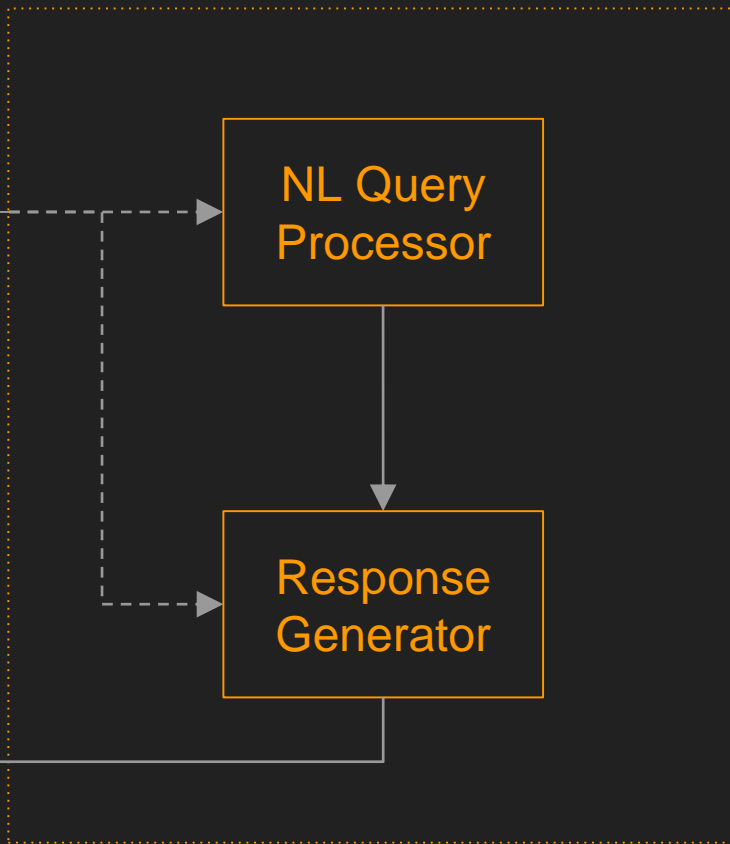


Client Server



Interface Manager

Response Processor



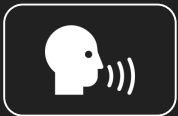
NL Query Processor

Response Generator



Client Server

Goal: To find connections of high goal scoring players for England



“Show connections of English players with more than 20 goals”

- > “Show England players”
- > “Show players with more than 20 goals”
- > “Show connections”



“Show connections of these players”

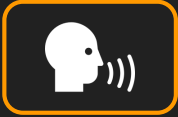


“Show English players with more than 20 goals”



“Show connections”

Goal: To find connections of high goal scoring players for England



“Show connections of English players with more than 20 goals”

- > “Show English players”
- > “Show players with more than 20 goals”
- > “Show connections”



“Show connections of these players”



“Show English players with more than 20 goals”



“Show connections”



Context

- Active/highlighted nodes
- Active filters
- Active visual encodings
- Operations & targets from previous query



(new/ current query)

Context

- Active/highlighted nodes
- Active filters
- Active visual encodings
- Operations & targets from previous query



(new/current query)

Individual

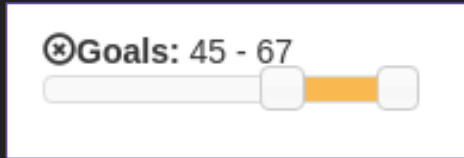
Sequential

Simultaneous

Find connections of wayne

Highlighting nodes directly connected to **Wayne Rooney**

- wayne rooney
- Wayne Hennessey



Find Ronaldo's connections

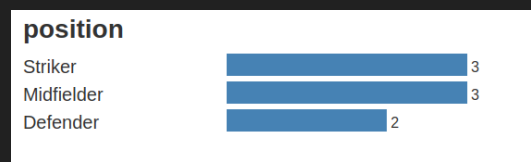
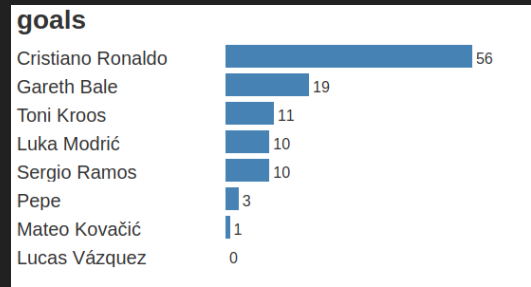
Highlighting nodes directly connected to **Cristiano Ronaldo**

- Cristiano Ronaldo
- João Moutinho
- Stephen Ward
- Zoltán Gera
- Robbie Brady
- David Meyler
- Daryl Murphy
- Wes Hoolahan
- Darren Randolph

Ronaldo and Rooney

Highlighting ⊗ Cristiano Ronaldo

- Find node(s)
- Find connections
- Find path



Find connections of wayne

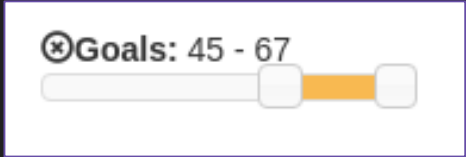
Highlighting nodes directly connected to

wayne rooney
Wayne Hennessey

Find Ronaldo's connections

Highlighting nodes directly connected to

Cristiano Ronaldo
João Moutinho
Stephen Ward
Zoltán Gera
Robbie Brady
David Meyler
Daryl Murphy
Wes Hoolahan
Darren Randolph



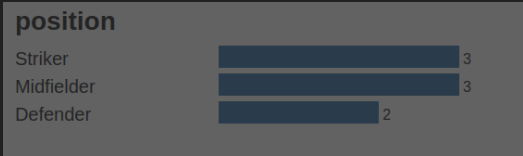
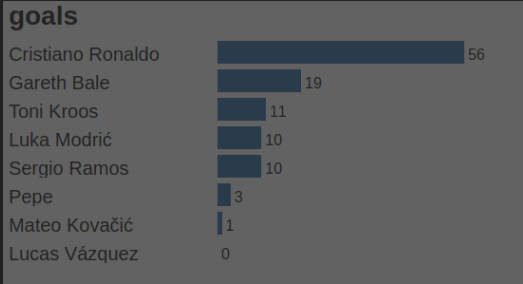
Ambiguity Widgets

Gao et al., UIST '15

Ronaldo and Rooney

☰ Highlighting ⊗ Cristiano Ronaldo

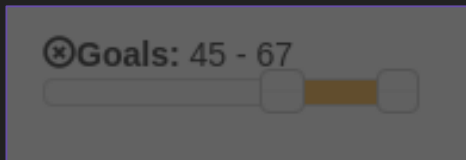
Find node(s)
Find connections
Find path



Find connections of wayne

Highlighting nodes directly connected to Wayne Rooney

- wayne rooney
- Wayne Hennessey



Find Ronaldo's connections

Highlighting nodes directly connected to Cristiano Ronaldo

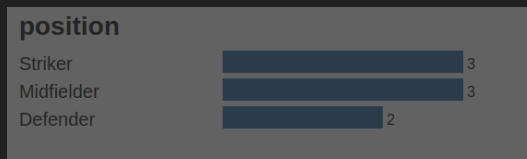
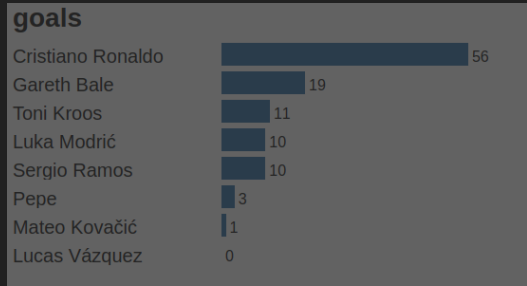
- Cristiano Ronaldo
- João Moutinho
- Stephen Ward
- Zoltán Gera
- Robbie Brady
- David Meyler
- Daryl Murphy
- Wes Hoolahan
- Darren Randolph

Query Manipulation Widgets

Ronaldo and Rooney

Highlighting ⊗ Cristiano Ronaldo

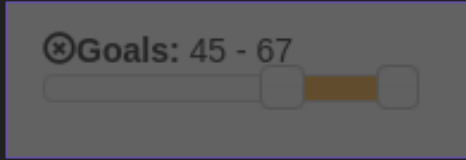
- Find node(s)
- Find connections
- Find path



Find connections of wayne

Highlighting nodes directly connected to

- wayne rooney
- Wayne Hennessey



Find Ronaldo's connections

Highlighting nodes directly connected to

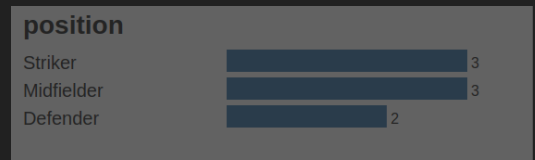
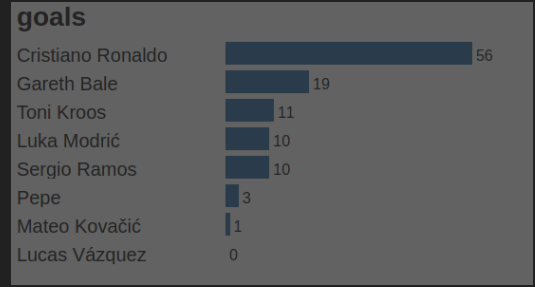
- Cristiano Ronaldo
- João Moutinho
- Stephen Ward
- Zoltán Gera
- Robbie Brady
- David Meyler
- Daryl Murphy
- Wes Hoolahan
- Darren Randolph

Operation Suggestion

Ronaldo and Rooney

☰ Highlighting ⊗ Cristiano Ronaldo

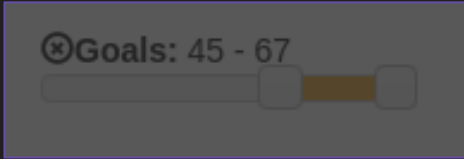
- Find node(s)
- Find connections
- Find path



Find connections of wayne

Highlighting nodes directly connected to Wayne Rooney

- wayne rooney
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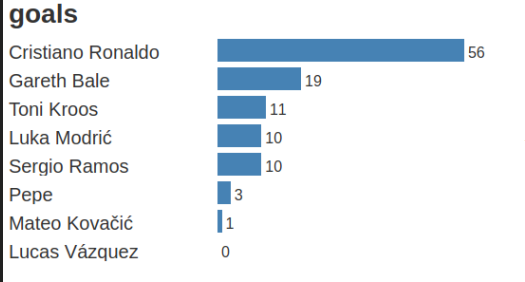


Find Ronaldo's connections

Highlighting nodes directly connected to Cristiano Ronaldo

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- João Moutinho
- Stephen Ward
- Zoltán Gera
- Robbie Brady
- David Meyler
- Daryl Murphy
- Wes Hoolahan
- Darren Randolph

Proactive Summary Chart Reordering



Ronaldo and Rooney

Highlighting ⊗ Cristiano Ronaldo

- Find node(s)
- Find connections
- Find path

Why support multimodal interaction?

**Iron Man 2
(2010)**



**Iron Man 2
(2010)**



User Study

Goals:

- Collect observational data on how people interact with network visualizations when they have the option of using multimodal input.
- Assess basic usability of the system
- Collect qualitative feedback on Orko's design and multimodal interaction

User Study

6 participants

Network of European soccer players

10 tasks (no training)

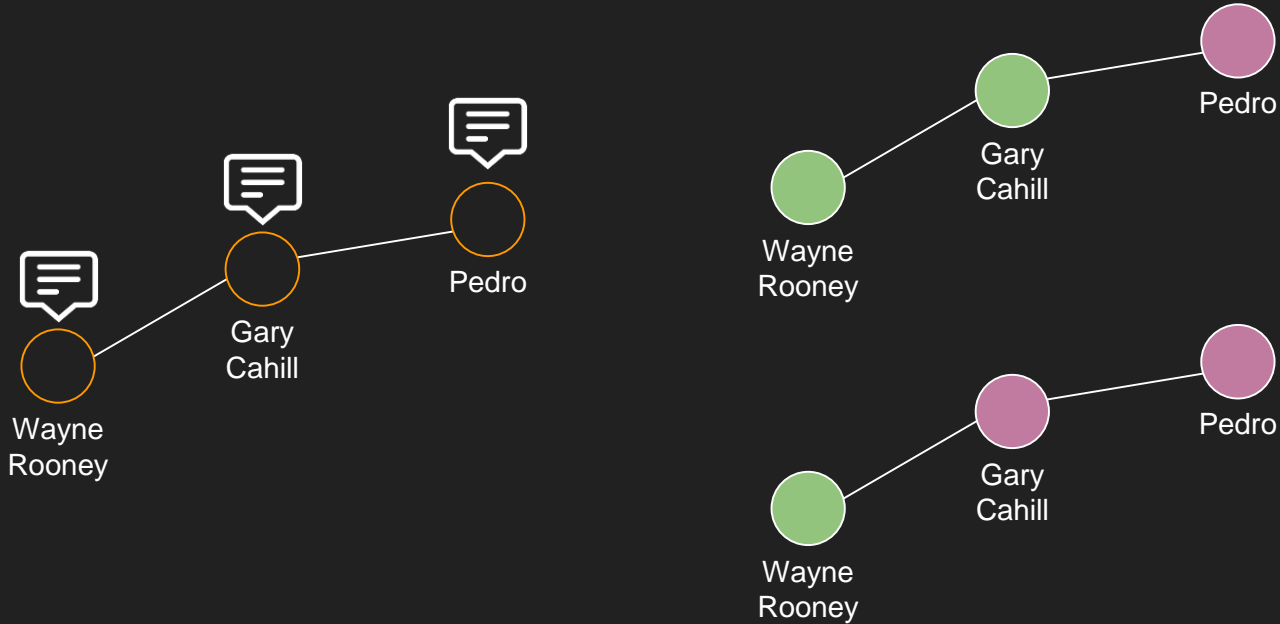
~30 min sessions

Sample tasks

- Show that Wayne Rooney and Pedro play for different teams (both club and national) but share a spot on a team with Gary Cahill.
[fact]*
- Name a FC Barcelona midfielder. Identify at least two non-Barcelona midfielders the player plays with.
[indirect question]

Sample task

- Show that Wayne Rooney and Pedro play for different teams (both club and national) but share a spot on a team with Gary Cahill.



	P1			P2			P3			P4			P5			P6				
	S	T	ST	S	T	TS	S	T	ST	S	T	ST	S	T	ST	S	T	ST	TS	
T1			1	2					1			1			1	1				
T2	2			1			1					1			1	1				
T3	2	2	1	3	1		1		1	3	1		3	1		2				
T4	2		1	3			4					3			6	3				
T5	2			2				1	1			1	2	4		4	1	1		
T6	1		1	1				2	1	1			1	3		4				
T7	1	1		2	3		1	1	1		1	1	3	1		2	2			
T8	1		1	1			1	1	1			1	2	1		1				
T9	2			2					2	2			2	1		1		2		
T10	2	2	2	8	1	2		6	2	2	5		2	5		2	3			1

S: Speech
T: Touch
ST: Speech+Touch
TS: Touch+Speech

Participants

	P1			P2			P3			P4			P5			P6				
	S	T	ST	S	T	TS	S	T	ST	S	T	ST	S	T	ST	S	T	ST	TS	
T1			1	2					1			1			1	1				
T2	2			1			1					1			1	1				
T3	2	2	1	3	1		1		1	3	1		3	1		2				
T4	2		1	3			4					3			6	3				
T5	2			2				1	1			1	2	4		4	1	1		
T6	1		1	1				2	1	1			1	3		4				
T7	1	1		2	3		1	1	1		1	1	3	1		2	2			
T8	1		1	1			1	1	1			1	2	1		1				
T9	2			2					2	2			2	1		1		2		
T10	2	2	2	8	1	2		6	2	2	5		2	5		2	3			1

S: Speech
 T: Touch
 ST: Speech+Touch
 TS: Touch+Speech

Participants

	P1			P2			P3			P4			P5			P6			
	S	T	ST	S	T	TS	S	T	ST	S	T	ST	S	T	ST	S	T	ST	TS
T1			1	2					1			1			1	1			
T2	2			1			1					1			1	1			
T3	2	2	1	3	1		1		1	3	1		3	1		2			
T4	2		1	3			4					3			6	3			
T5	2			2				1	1			1	2	4		4	1	1	
T6	1		1	1				2	1	1			1	3		4			
T7	1	1		2	3		1	1	1		1	1	3	1		2	2		
T8	1		1	1			1	1	1			1	2	1		1			
T9	2			2					2	2			2	1		1		2	
T10	2	2	2	8	1	2		6	2	2	5		2	5		2	3		1

Input style

S: Speech
T: Touch
ST: Speech+Touch
TS: Touch+Speech

Participants

Tasks

		P1			P2			P3			P4			P5			P6			
		S	T	ST	S	T	TS	S	T	ST	S	T	ST	S	T	ST	S	T	ST	TS
T1				1	2					1			1			1	1			
T2	2				1			1					1			1	1			
T3	2	2	1		3	1		1		1	3	1		3	1		2			
T4	2		1		3			4					3		6		3			
T5	2				2				1	1			1	2	4		4	1	1	
T6	1		1		1				2	1	1			1	3		4			
T7	1	1			2	3		1	1	1		1	1	3	1		2	2		
T8	1		1		1			1	1	1			1	2	1		1			
T9	2				2					2			2	2	1		1		2	
T10	2	2	2		8	1	2		6	2	2	5		2	5		2	3		1

S: Speech
 T: Touch
 ST: Speech+Touch
 TS: Touch+Speech

Participants

	P1			P2			P3			P4			P5			P6				
	S	T	ST	S	T	TS	S	T	ST	S	T	ST	S	T	ST	S	T	ST	TS	
T1			1	2					1			1			1	1				
T2	2			1			1					1			1	1				
T3	2	2	1	3	1		1	1	1	3	1		3	1		2				
T4	2		1	3			4					3		6		3				
T5	2			2				1	1			1	2	4		4	1	1		
T6	1		1	1				2	1	1			1	3		4				
T7	1	1		2	3		1	1	1		1	1	3	1		2	2			
T8	1		1	1			1	1	1			1	2	1		1				
T9	2			2					2	2			2	1		1		2		
T10	2	2	2	8	1	2	6	2	2	5	2	5	2	5	2	3				1

1 sequential speech+touch

S: Speech
 T: Touch
 ST: Speech+Touch
 TS: Touch+Speech

Tasks

Participants

Tasks

		Participants																					
		P1			P2			P3			P4			P5			P6						
		S	T	ST	S	T	TS	S	T	ST	S	T	ST	S	T	ST	S	T	ST	TS			
T1			1	2				1				1	1		1		1						
T2	2			1				1			1		1		1		1						
T3	2	2	1	3	1			1	1		3	1			3	1			2				
T4	2	1		3				4				3		6		3							
T5	2			2				1		1			1		2	4			4	1	1		
T6	1	1		1				2		1			1	3		4							
T7	1	1			2	3			1	1	1			1	1	1	3	1	2		2		
T8	1	1		1				1		1	1	1			1	1	1	2					
T9	2			2				2				2		2		1			1		2		
T10	2	2	2	8	1	2			6		2	2		5		2		5	2		3	1	

S: Speech
T: Touch
ST: Speech+Touch
TS: Touch+Speech

Participants

		Participants																		
		P1			P2			P3			P4			P5			P6			
		S	T	ST	S	T	TS	S	T	ST	S	T	ST	S	T	ST	S	T	ST	TS
Tasks	T1			1	2					1			1			1	1			
	T2	2			1			1					1			1	1			
	T3	2	2	1	3	1		1		1	3	1		3	1		2			
	T4	2		1	3			4					3	6			3			
	T5	2			2			1	1	1	1			2	4		4	1	1	
	T6	1		1	1				2	1	1			1	3		4			
	T7	1	1		2	3		1	1	1		1	1	3	1		2	2		
	T8	1		1	1			1	1	1			1	2	1		1			
	T9	2			2					2	2			2	1		1		2	
	T10	2	2	2	8	1	2		6	2	2	5		2	5		2	3		1

No simultaneous use of modalities

S: Speech
 T: Touch
 ST: Speech+Touch
 TS: Touch+Speech

Participants

Tasks

		P1			P2			P3			P4			P5			P6			
		S	T	ST	S	T	TS	S	T	ST	S	T	ST	S	T	ST	S	T	ST	TS
T1				1	2					1			1			1	1			
T2	2				1			1					1			1	1			
T3	2	2	1		3	1		1		1	3	1		3	1		2			
T4	2		1		3			4					3		6		3			
T5	2				2				1	1			1	2	4		4	1	1	
T6	1		1		1				2	1	1			1	3		4			
T7	1	1			2	3		1	1	1		1	1	3	1		2	2		
T8	1		1		1			1	1	1			1	2	1		1			
T9	2				2					2	2			2	1		1		2	
T10	2	2	2		8	1	2	6	2		2	5		2	5		2	3		1

S: Speech
T: Touch
ST: Speech+Touch
TS: Touch+Speech

Only three instances of sequential input where touch preceded speech

Participants

Tasks

		P1			P2			P3			P4			P5			P6			
		S	T	ST	S	T	TS	S	T	ST	S	T	ST	S	T	ST	S	T	ST	TS
T1				1	2					1			1			1	1			
T2	2				1			1					1			1	1			
T3	2	2		1	3	1		1		1	3	1		3	1		2			
T4	2			1	3			4						6			3			
T5	2				2				1	1			1	2	4		4	1	1	
T6	1			1	1				2	1	1			1	3		4			
T7	1	1			2	3		1	1	1		1	1	3	1		2	2		
T8	1			1	1			1	1	1				2	1		1			
T9	2				2					2				2	1		1		2	
T10	2	2		2	8	1	2		6	2		2	5		2	5	2	3		1

S: Speech
T: Touch
ST: Speech+Touch
TS: Touch+Speech

30 instances of sequential input where speech preceded touch

Participants

Tasks

		P1			P2			P3			P4			P5			P6			
		S	T	ST	S	T	TS	S	T	ST	S	T	ST	S	T	ST	S	T	ST	TS
T1				1	2					1			1			1	1			
T2		2			1			1					1			1	1			
T3		2	2	1	3	1		1		1	3	1		3	1		2			
T4		2		1	3			4					3		6		3			
T5		2			2				1	1			1	2	4		4	1	1	
T6		1		1	1				2	1	1			1	3		4			
T7		1	1		2	3		1	1	1		1	1	3	1		2	2		
T8		1		1	1			1	1	1			1	2	1		1			
T9		2			2					2			2	2	1		1		2	
T10		2	2	2	8	1	2		6	2	2	5		2	5		2	3		1

S: Speech
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Speech (individually) was the dominant input modality (~50%)

	P1	P2	P3	P4	P5	P6	Avg.
Overall SUS scores (out of 100)	80	70	82.5	80	52.5	87.5	75.42
Would want to use the system frequently (out of 5)	4	5	5	5	3	5	4.5
Found various functions well integrated (out of 5)	5	5	4	3	5	4	4.33
Natural language query interpretation (out of 5)	4	4	3	4	4	5	4

- “It [multimodal interaction] was fun to use and a very intuitive way to explore a network”
- “I was surprised by the speech feature. I did not expect it to work as well as it did”
- “...having worked with many visualization programs before, having to go through and manually clicking is really annoying especially when you have a ton of dropdowns. So I really like the speech feature, I know it’s still in a rudimentary stage but it does a really good job”

- “It was a little **frustrating when the system did not understand my voice or did not react at all to voice**”
- “If the system used the keyboard, an **auto-complete function would be very helpful**”

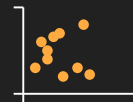
What's next?



- Exploring layout modification, alternative representations, and network metrics

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- Exploring layout modification, alternative representations, and network metrics
- Exploring other visualizations and data domains



What's next?

- Exploring layout modification, alternative representations, and network metrics
- Exploring other visualizations and data domains
- Toolkits to incorporate multimodal interaction



NL4DV: Toolkit for Natural Language Driven Data Visualization

Arjun Srinivasan*

John Stasko†

Georgia Institute of Technology

ABSTRACT

Developing natural language interfaces for visualization systems is a challenging task and requires system developers to spend time and effort on implementing Natural Language Processing (NLP) components necessary to convert natural language queries into visualizations. Especially for developers without a background in NLP, this learning curve can be even more challenging and time consuming. We are developing the Natural Language Driven Data Visualization (*NL4DV*) toolkit that provides high-level functions developers can use to create natural language-driven data visualization systems.

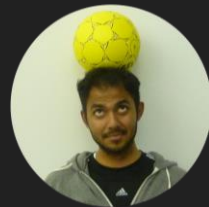
We are creating a toolkit called NL4DV to provide developers and designers of visualization systems with high-level functions that they can use to add natural language query interfaces as extensions to their existing systems or build systems entirely driven by natural language.

2 NL4DV

Figure 1 highlights (in gray) the four high-level components and some of their intermediate inputs and outputs (in white) that are required to implement a natural language driven visualization system. NL4DV is implemented in Python and is provided as a python package. As shown in Figure 1, it comes with a built-in query pro-

Listening...

Thank you



Arjun Srinivasan



John Stasko



information interfaces

Creating Natural Data Visualization and Analysis Environments

Team Members: Arjun Srinivasan, John Stasko

- ACTIVE PAPERS**
 - Orko: Facilitating Multimodal Interaction for Visual Network Exploration and Analysis - InfoVis 2017
 - Affordances of Input Modalities for Visual Data Exploration in Immersive Environments - Workshop on Immersive Analytics 2017
 - Natural Language Interfaces for Data Analysis with Visualization: Considering What Has and Could Be Asked - EuroVis 2017
 - NL4DV: Toolkit for Natural Language Driven Data Visualization (Poster) - VIS 2016
- DOWNLOADS**
 - VIDEO: Orko Introduction, InfoVis '17 (37 MB mp4)
 - VIDEO: Orko Usage Scenario, InfoVis '17 (52 MB mp4)

We live in a data-rich era. Data visualization and exploration capabilities are becoming more widely used in a variety of disciplines including business, health, education, and public policy, to name just a few. Currently, people use visualization systems on desktop and laptop computers and typically interact via keyboard and mouse. Such interactions, while useful, pale in comparison to the natural, fluid interactions presented in futuristic feature films such as "Minority Report" and "Iron Man" where characters interact with large, projected wall displays through speech, gaze, and gesture. To move towards such futuristic interfaces, we must develop new forms of Natural User Interfaces (NUIs) employing multimodal interactions

<https://www.cc.gatech.edu/gvu/ii/naturalvis/>